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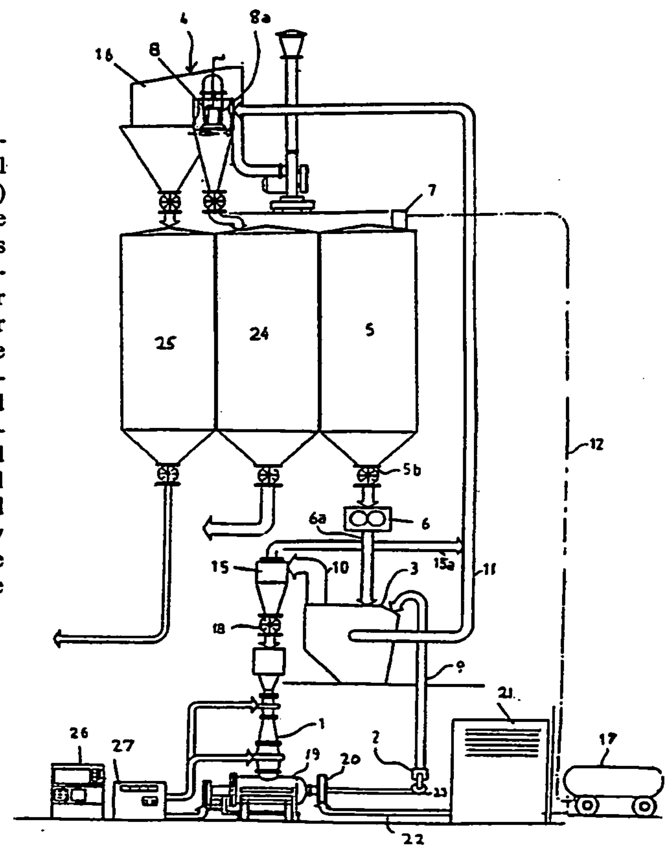
(54) Title: METHOD AND EQUIPMENT FOR THE PRODUCTION OF PARTICULARLY FINELY DIVIDED DRY POWDERS

## (57) Abstract

Method and equipment for the production of particularly finely divided dry powders out of an input material consisting of coarser particles by means of a jet grinder (2) provided with a mechanical feeder (1). In this method, the solids/working-gas jet rushing out of the jet grinder (2) is passed into a centrifugal classifier (3), wherein the fine material and the coarse material are separated from each other in view of recirculating the coarse material into the feeder (1) of the jet grinder and passing the fine material into the separation system (4) for fine product. The invention is characterized in that the input material is passed from the feed silo (5) into a mechanical crusher (6) so as to produce micro-fissures in the particles of the input material and to grind more readily ground particles, and that the input material that has passed through the mechanical crusher (6) is passed further into a centrifugal classifier (3) so as to separate any ready fine material present in the input material from the rest of the material before the input material is fed into the feeder (1) of the jet grinder.



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# Method and equipment for the production of particularly finely divided dry powders

The subject of the present invention is a method and an equipment for the production of particularly finely divided dry powders out of an input material consisting of coarser particles by means of a jet grinder provided with a mechanical feeder. In this method, the solids/working-gas jet rushing out of the jet grinder is passed into a centrifugal classifier, wherein the fine material and the coarse material are separated from each other in view of recirculating the coarse material into the feeder of the jet grinder and passing the fine material into the separation system for fine product.

In jet grinding, the input material to be ground is fed by means of a mechanical feeder, such as a twin-valve feeder, to among the pressurized working gas so as to be fluidized. The working-gas/solids mix produced is divided into two or more component flows, and these component flows are accelerated through conically arranged accelerating nozzles to such a high velocity, preferably about 300 m/s, that a maximum amount of particles coming out of the different nozzles are broken into fine product when colliding against each other, which said fine product can be separated by a sharp classification from the coarse fraction to be recirculated to among the original input material of the jet grinder.

It is an essential problem of the jet grinder technology that the input material is highly unhomogeneous, containing an abundance of oversize particles and also an abundance of very small particles. This is why it is very difficult to control the grinding process. Depending on the particle size, different particles, viz., require different quantities of energy in order to be accelerated to the desired velocity in the accelerating nozzles of the jet grinder. Since the

grinding energy used in jet grinding is introduced in the form of pressurized working gas, such as compressed air, the quantity of energy to be used depends mainly on the working-gas/solids ratio fed into the grinder.

Usually the input material contains some proportion of ready fine product right from the beginning, so that this proportion also requires its share of the energy contained in the compressed air in being accelerated to the velocity used in grinding and, moreover, the volume weight of this fine product proportion is low, so that this fact also makes it more difficult to produce a correct working-gas/solids ratio in the input of the jet grinder. The input material always also contains some amount of oversize particles, which require an unreasonable amount of energy to be accelerated to the velocity required in the grinding. Since a sufficiently high velocity is mostly not achieved, these oversize particles are gathered in the circulation between the classifier and the jet grinder and hamper the feeding of new input material into the process.

The object of the present invention is to eliminate the problems described above and to provide an optimal particle size for the input material fed into the jet grinder, so that the overall energy consumption of the process is lowered at the same time as the grinding result is improved. This has been achieved by means of a method which is characterized in that the input material is passed from the feed silo into a mechanical crusher so as to produce microfissures in the particles of the input material and to grind more readily ground particles, and that the input material that has passed through the mechanical crusher is passed further into a centrifugal classifier so as to separate any ready fine material present in the input material from the rest of the material before the input material is fed into the feeder of the jet grinder.

In the method in accordance with the invention, microfissures and cracks are formed by means of the mechanical crusher into the solid particles of the input material, the particles being ground readily at the said fissures and cracks in the grinding stage taking place in the jet grinder and based on collision. Moreover, any oversize particles are crushed to the input particle size optimal for jet grinding. In the centrifugal classifier following after the crusher, all fine material present in the input material is separated before the input material is fed into the jet grinder. Thus, the input material fed into the jet grinder consists of particles belonging to a very narrow range of particle size. The particle size aimed at is small enough so that it can be accelerated with good efficiency to the velocity required in jet grinding but, however, large enough so that it can no longer be retarded before the collision at the outlet side of the accelerating nozzles as the flow velocity of the working gas is changed.

The other characteristics of the invention come out from the attached claims 1 to 15.

In the following, the invention will be described in more detail with the aid of an example, reference being made to the attached drawing, wherein

Figure 1 illustrates the grinding of a particle to fine product in accordance with a recommended embodiment of the invention,

Figure 2 shows the construction of principle of a pregrinding or autogenous pocket used in connection with pneumatic conveyance,

Figure 3 shows an example of a complete set of equipment used for carrying out the invention as a flow diagram, and

Figure 4 shows a second example of an equipment used for carrying out the invention, wherein the pre-crushing and the fine-product separation are omitted.

In the method in accordance with the invention, particularly finely divided powders are produced out of an input material consisting of coarser particles by means of a jet grinder 2 provided with a mechanical feeder 1. Preferably a jet grinder 2 provided with a twin-valve feeder 1 is used, such as a pressure chamber grinder. The material ground in the jet grinder 2 by means of working-gas/solids jets colliding against each other is passed along with the working-gas flow into a centrifugal classifier 3, wherein the coarse material and the fine material are separated from each other. The fine material is passed into the fine-product separation system 4, and the coarse material is passed back into the feeder 1 of the jet grinder. The input material is passed from a feed silo 5 of the equipment into a mechanical crusher 6, wherein the largest and the most readily ground particles are crushed and microfissures are formed into harder particles, which remain uncrushed, the said particles being ground readily at the fissures in the treatment in the jet grinder. The input material which has passed through the mechanical crusher and which has been ground partly is passed further into the centrifugal classifier 3 so as to separate any ready fine material present in the input material from the rest of the material before the input material is passed into the feeder 1 of the jet grinder.

New input material is usually supplied to the equipment by means of a tank vehicle 17. The tank vehicle 17 is unloaded into the feed silo 5 of the equipment by means of a pneumatic conveyor line 12. According to a preferred embodiment, an accelerating nozzle 13 is provided at the outlet end of the pneumatic conveyor line 12, which said nozzle ends in an autogenous pocket 7 provided at the upper end of the feed silo 5. By means of this solution, input material can already be pre-crushed partly in connection with the unloading of the tank vehicle 17. The input material is acceler-

ated in the accelerating nozzle 13 installed at the final end of the pneumatic conveyor line 12 so that a maximum proportion of the energy contained in the compressed air is converted to kinetic energy of the particles, whereupon the particles are made to collide against each other in the autogenous pocket 7 mounted after the accelerating nozzle 13. The velocity of the material-gas flow rushing into the autogenous pocket 7 is preferably of an order of 20 to 100 m/s. The rear or impact face 7a of the autogenous pocket 7 is preferably shaped so that it gives the material-gas flow rushing into the autogenous pocket 7 a loop-shaped flow path, as is indicated by an arrow in Fig. 2, whereby, on their way out of the autogenous pocket, the material particles are forced into the path of the material jet coming into the autogenous pocket 7. In this pre-crushing stage, a grinding on the macro level takes place, whereby any loose bonds in large particles are broken and any cracks and flaws in the particles become larger by the effect of collisions. The grinding taking place in the autogenous pocket 7 can be intensified by feeding additional material into the autogenous pocket into its collision zone from above the pocket, whereby the probability of collision is increased. The additional material may, for example, consist of such oversize fraction as has been screened off the input material before the mechanical crusher because of its size that is excessively large for the crusher.

In connection with the pneumatic conveyance, the feed material can be dried at the same time by means of the energy produced in the pressurization of the compressed air. If a sufficient amount of heat is not obtained from the compressing, additional heating of the compressed air must be used, e.g. by superheating it under pressure.

In the fine-product separation system 4, the fine material is separated from the working gas by means

of a pneumatic cyclone (8) into two fractions of different types, one of which contains the particles smaller than the separation limit but, yet, close to the said limit, and the other one contains the superfine particles, which have a large surface area in relation to their weight.

In the preferred embodiment of the invention, the mechanical crusher 6 is a roll crusher, in which the speed of rotation of the rolls may be about 5 to 10 m/s. An equipment that includes a roll crusher 6 is shown in Fig. 3. The input material introduced into the feed silo 5 is fed at a uniform speed into the roll crusher 6, e.g., by means of a closing feeder installed at the outlet opening 5b of the feed silo. By the effect of the rolls of the roll crusher 6, the oversize particles in the input material are broken, and microfissures are formed in the particles that are not broken. After the crushing treatment, the input material is passed along the outlet duct 6a of the roll crusher into the centrifugal classifier 3, wherein the fine material and the coarse material contained in the input material are separated from each other. The coarse material is passed along the duct 10 into a multicyclone 15, wherein the coarse material is separated from the working gas. The working gas, usually compressed air, is passed along the duct 15a to the outlet duct 11 for the fine-product fraction coming from the centrifugal classifier 3, which said duct ends in the fine-product separation system 4, and the coarse product is fed into the hydraulically operated twin-valve feeder 1 of the jet grinder, e.g., by means of a closing feeder 18 mounted at the bottom of the multicyclone 15. Thus, the multicyclone 15 must be dimensioned so that fractions coarser than the separation limit of the classification cannot pass along with the working gas into the fine product. The operation of the twin valve 1 is described, e.g. in the published International Patent Application WO86/02287.

In the twin-valve feeder 1, the input material is pressurized and dropped batchwise into the equalizing tank 19 of the jet grinder equipment, from where it is passed by means of a hydraulically operated screw feeder at a controlled speed into the fluidization space 20. In the fluidization space 20 the input material to be ground is mixed with the compressed air coming from the compressor 21 along the duct 22. The fluidized solids-working-gas mixture under high pressure rushes through at least one bisecting device 23 into the substantially conically arranged grinding nozzles in the jet grinder 2, in which said nozzles the material particles are, owing to an expansion of the working gas, accelerated to the velocity (about 300 m/s) required for the collision producing the grinding. The material/working-gas mix rushing out of the jet grinder 2 is passed along the outlet duct 9 into the centrifugal classifier 3, from which the fine product produced is passed into the fine-product separation system 4 along the duct 11, and the coarse material remaining after the jet grinding is recirculated into the jet grinder 2 through the multi-cyclone 15. The outlet duct 11 ends in the vortex chamber cyclone 8 of the fine-product separation system, in which cyclone there is a vortex tube bottom closed by an intermediate bottom and an adjustable fine-product opening 8a placed at the side of the vortex tube. The vortex chamber cyclone 8 is preferably also provided with tangentially directed openings 8b for additional air, by means of which said openings the classification taking place in the cyclone can be adjusted and intensified. The working gas that has been made substantially free from solid matter is passed into a textile filter 16, where the working gas is made free from any superfine product that is remaining in it. The "coarser" proportion of the fine product is passed from the bottom part of the vortex chamber cyclone 8 into a storage silo 24, and its superfine proportion into a storage silo 25,

from which said silos 24, 25 the products formed can be measured by means of adjustable feeders to final products of different properties. All the operations of the equipment are controlled from the control centre 26 of the equipment, and the hydraulically operated members 1, 19 of the equipment receive their drive power from the hydraulic power source 27.

In the case of some materials, it may be preferable to use a two-stage roll crushing, whereat the space between the rolls is larger in the first roll crusher than in the second roll crusher.

If a rotor crusher is used as the mechanical crusher 6, as is shown in Fig. 4, the input material is passed onto the breaking disc 6b of the rotor crusher through the duct 5a. The breaking disc 6b is driven by and electric motor 6c. The breaking disc 6b flings the particles of the input material against the surrounding casing 6d. During the operation of the equipment, a material bed 6e consisting of the particles to be crushed is gathered in the casing 6d, from which bed the particles flung by the breaking disc 4 bounce first diagonally upwards and thereupon, following the face of the bed and of the casing, downwards so that the crushing of the material takes place mainly as the particles collide against each other in the air. The material that remains coarser in the crusher is lowered by the effect of the force of gravity into the recirculation duct 6f, which recirculates it back into the crusher for repeated crushing treatment. On the contrary, the more finely divided material produced by the crusher rises along with the air flow produced by the crusher up into the duct 6a starting above the breaking disc 6b, which said duct 6a passes into the centrifugal classifier 3, from which the coarse material is passed into the twin-valve feeder 1 of the jet grinder. The outlet duct of the jet grinder 2 is provided with a filter for the separation of the solid matter from the working gas to be

passed into the rotor crusher 6, by means of which said working gas the more finely divided material is transferred into the centrifugal classifier and the input material is dried.

The invention is suitable for the production of almost all powders that are used as fine, of which the most important ones are the binder agents used by the construction industry, paper and plastic fillers, coatings and pigments, as well as various foodstuffs, such as grain and spices. Refining of minerals is also possible by means of the equipment of the invention. Thus, as the input material it is possible to use, for example, blast-furnace slag used for the production of finely divided and very finely divided products which have a large specific area and which are used in the way of cement, the composition of the said slag being close to the burnt clinker used for the manufacture of cement, as well as burnt cement clinker, which is required for the manufacture of cement products used for special purposes.

As two fine finished products of highly different types are produced in the apparatus in accordance with the invention, by varying the ratios of these two products, e.g. in the preparation of concrete, it is possible to act upon various properties of the concrete produced in the desired way, such as upon initial and ultimate strength, workability, and water retaining capacity.

Water-granulated slag is also moist after the granulation, so that in connection with its treatment it is suitable to make use of the drying possibility in accordance with the invention in connection with the pneumatic conveyance of the material.

It comes out from the sketch of principle in Fig. 1 that a large initial particle almost always has cracks, inclusions, pores, and border faces resulting from unhomogeneity of the material, produced either in nature or in earlier processes. It is typical of such

sections of discontinuity that the particle is readily broken by the effect of an impact-type strain which is produced in a collision of particles against a solid face or against other particles, as takes place in the autogenous pocket in the equipment of the invention. The remaining parts are either more elastic and more homogeneous or stronger than the particle of starting material. This is why further grinding based on a grinding mechanism of the same type would consume a lot of energy, because the particles concerned have already proved resistant to impacts produced in the pre-crushing. Thus, in the method of the present invention, the next stage in the process is an intermediate crushing based on a compression taking place in an autogenous bed and on the strains produced therein, in which said crushing all oversize particles are forced to be broken into particles not exceeding a certain size, whereby the material is ground partly to completely finished product and partly receives new microfissures into the particles. Owing to these microfissures, the energy consumption in the next stage, which is the jet grinding, is lowered by up to 30 per cent. This has a great importance for the grinding economy in view of the fact that the consumption of energy in the pre-crushing and intermediate crushing is only 1 to 10 kWh/t, whereas the consumption of energy in the final grinding proper is 50 to 250 kWh/t, in conventional jet grinders even 500 to 1500 kWh/t.

WHAT IS CLAIMED IS:

1. Method for the production of particularly finely divided dry powders out of an input material consisting of coarser particles by means of a jet grinder (2) provided with a mechanical feeder (1), in which said method the solids/working-gas jet rushing out of the jet grinder (2) is passed into a centrifugal classifier (3), wherein the fine material and the coarse material are separated from each other in view of recirculating the coarse material into the feeder (1) of the jet grinder and passing the fine material into the separation system (4) for fine product, c h a r a c t e r i z e d in that the input material is passed from the feed silo (5) into a mechanical crusher (6) so as to produce micro-fissures in the particles of the input material and to grind more readily ground particles, and that the input material that has passed through the mechanical crusher (6) is passed further into a centrifugal classifier (3) so as to separate any ready fine material present in the input material from the rest of the material before the input material is fed into the feeder (1) of the jet grinder.

2. Method as claimed in claim 1, c h a r a c t e r i z e d in that the input material is pre-crushed in connection with the filling of the feed silo (5) in an autogenous pocket (7) by means of the kinetic energy produced in connection with the pneumatic conveyance.

3. Method as claimed in claim 2, c h a r a c t e r i z e d in that the input material is dried in connection with the pneumatic conveyance by means of energy produced in the compressing of the compressed air.

4. Method as claimed in claim 3, c h a r a c t e r i z e d in that in the fine-product separation system (4), the fine material is separated from the working gas by means of a pneumatic cyclone (8) into

two fractions of different types, one of which contains the particles smaller than the separation limit but, yet, close to the said limit, and the other one contains the superfine particles, which have a large surface area in relation to their weight.

5. Method as claimed in any of the preceding claims, c h a r a c t e r i z e d in that by means of the method, binder agents used by the construction industry, paper and plastic fillers, coatings and pigments are manufactured and grain and spices are treated.

6. Equipment for carrying out the method as claimed in claim 1, which said equipment comprises a jet grinder (2) provided with a mechanical feeder (1) and a centrifugal classifier (3) provided in the outlet duct (9) of the said jet grinder, the duct (10) of the said classifier for the coarse material terminating in the feeder (1) of the jet grinder and the duct (11) for the fine material terminating in the fine-product separation system (4), c h a r a c t e r i z e d in that the equipment further comprises a feed silo (5) and a mechanical crusher (6) connected to the outlet opening (5b) of the said silo, the outlet duct (6a) of the said crusher (6) being directly connected to the centrifugal classifier (3).

7. Equipment as claimed in claim 6, c h a r a c t e r i z e d in that at the outlet end of the pneumatic conveyor line (12), which operates as the filling system of the feed silo (5), an accelerating nozzle (13) is provided, which ends in an autogenous pocket (7) provided at the top end of the feed silo (5).

8. Equipment as claimed in claim 7, c h a r a c t e r i z e d in that the rear or impact face (7a) of the autogenous pocket (7) is shaped so as to give the material-gas flow rushing into the autogenous pocket (7) a loop-shaped flow path.

9. Equipment as claimed in claim 8, c h a r a c t e r i z e d in that the top wall of the

autogenous pocket (7) is provided with an inlet opening (7b) for additional material.

10. Equipment as claimed in claim 9, c h a r a c t e r i z e d in that the mechanical crusher (6) is a roll crusher, in which the speed of rotation of the rolls is about 5 to 10 m/s.

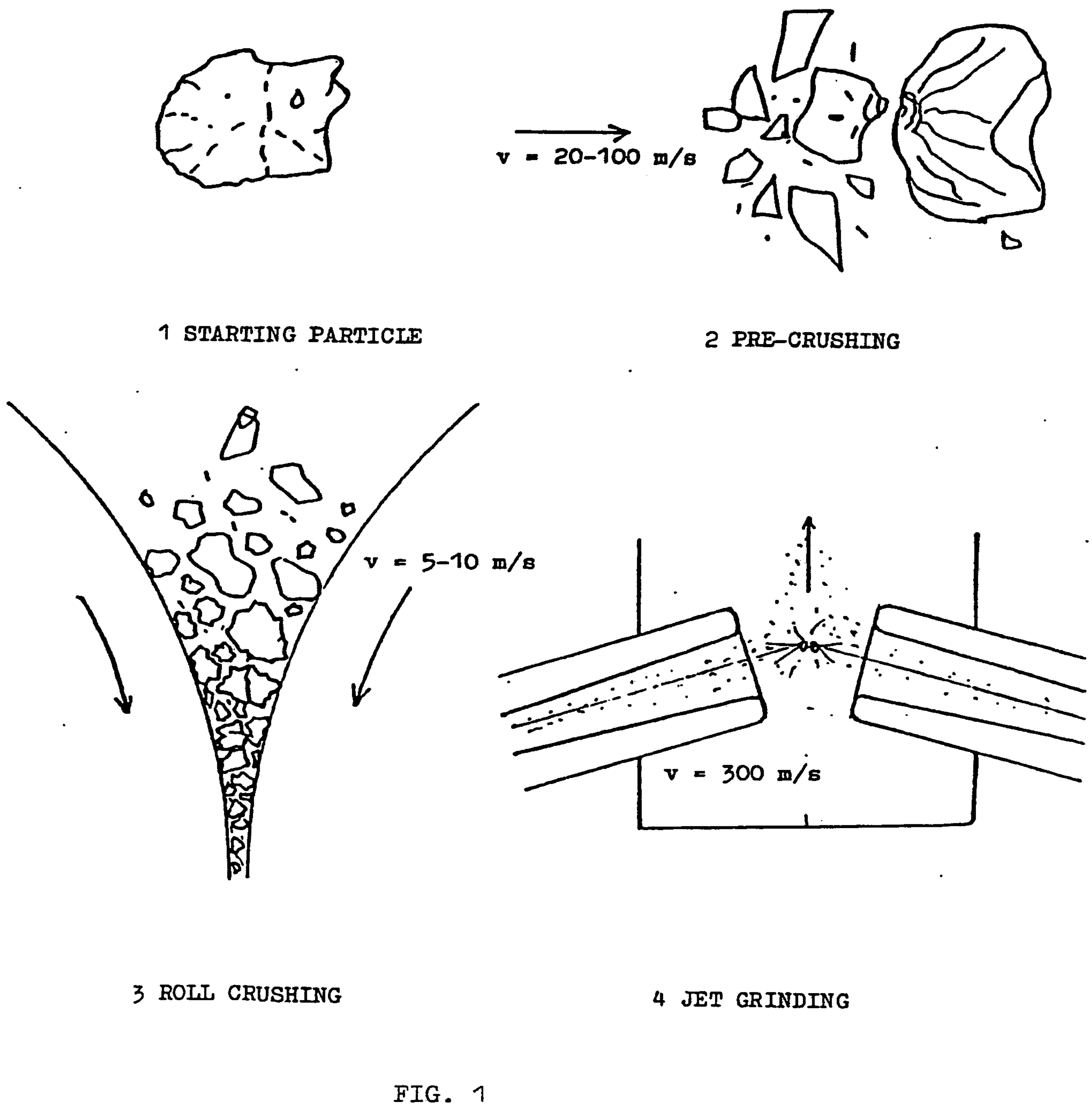
11. Equipment as claimed in claim 9, c h a r a c t e r i z e d in that the mechanical crusher (6) is a rotor crusher, from which the crushed material is arranged so as to pass along with the working-gas flow into the centrifugal classifier (3).

12. Equipment as claimed in claim 11, c h a r a c t e r i z e d in that the outlet duct (9) of the jet grinder (2) is provided with a filter (14) for the separation of solid matter from the working gas to be passed into the rotor crusher (6).

13. Equipment as claimed in claim 10 or 12, c h a r a c t e r i z e d in that a multicyclone (15) is provided in the outlet duct (10) for the coarse-product fraction in the centrifugal classifier (3) for the separation of the air from the coarse product.

14. Equipment as claimed in claim 13, c h a r a c t e r i z e d in that the fine-product separation system (4) provided in the duct (11) for the fine product in the centrifugal classifier (3) comprises a vortex chamber cyclone (8), which has a vortex-tube bottom closed by an intermediate bottom and an opening for fine product, located at the side of the vortex tube, as well as a textile filter (16) provided in the air exhaust duct of the vortex chamber cyclone (8).

15. Equipment as claimed in claim 14, c h a r a c t e r i z e d in that the vortex chamber cyclone (8) is provided with tangentially directed openings (8a) for additional air for the purpose of controlling and intensifying the classification taking place in the cyclone.




1 STARTING PARTICLE

2 PRE-CRUSHING

3 ROLL CRUSHING

4 JET GRINDING

FIG. 1

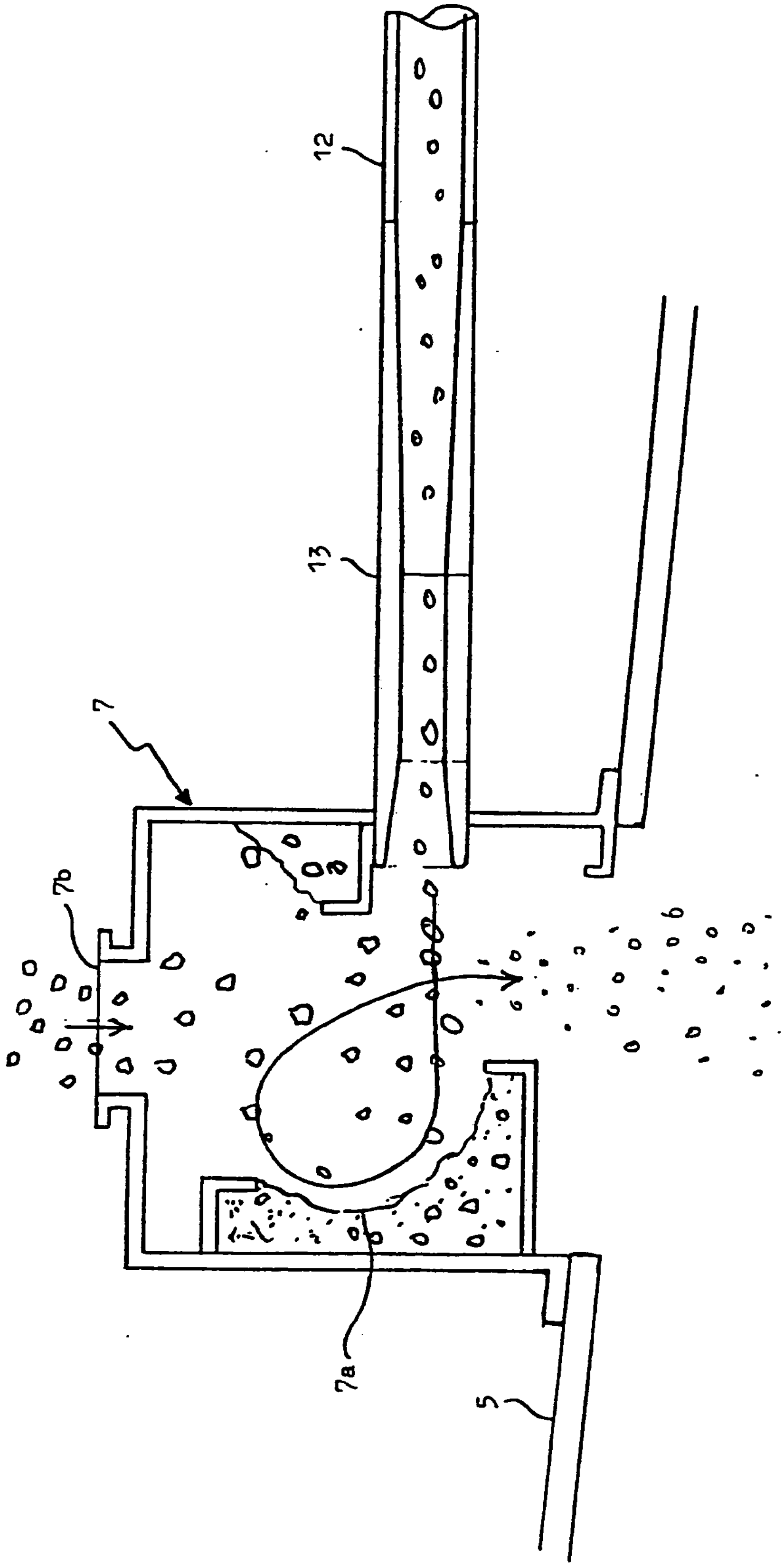



FIG. 2

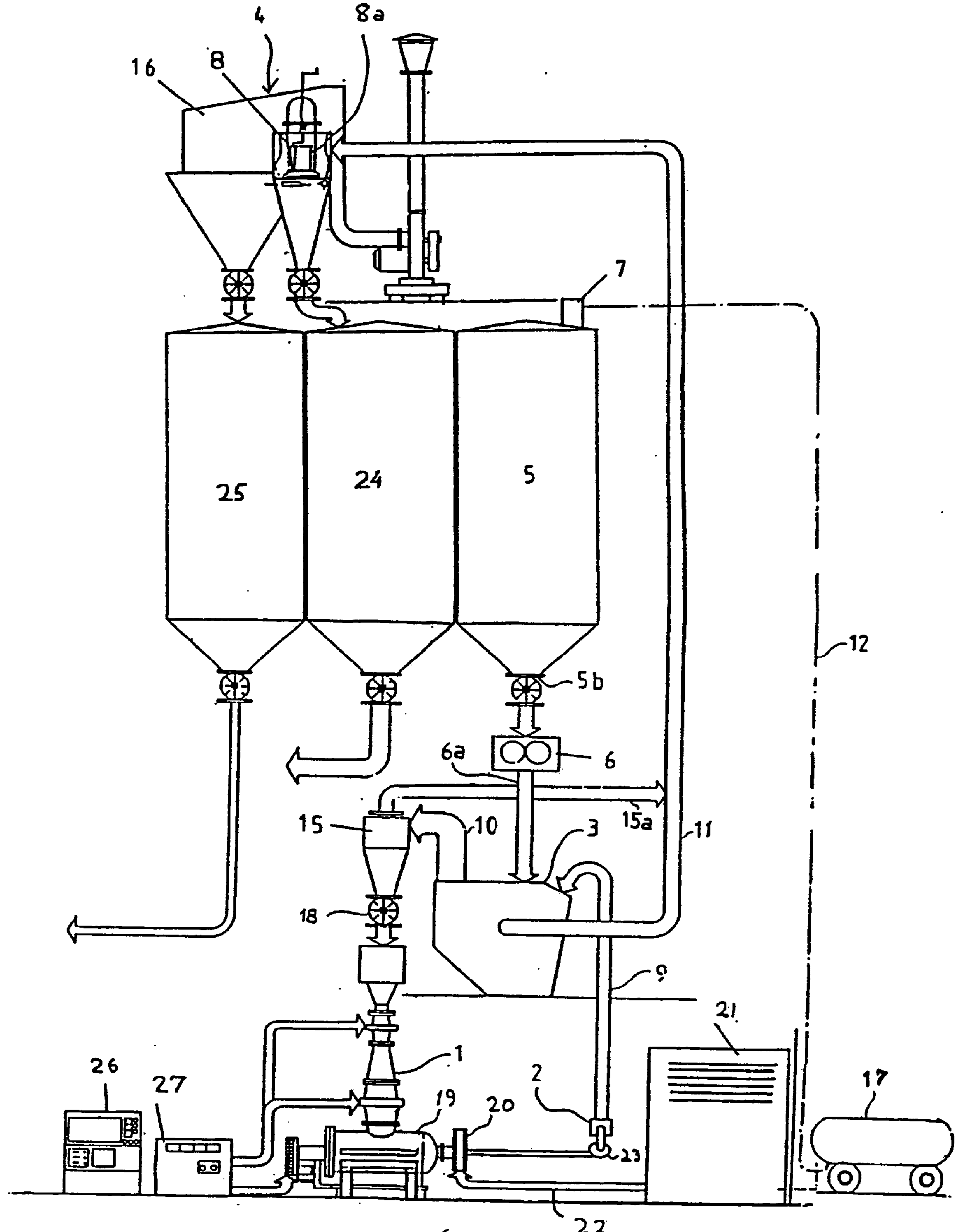

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FIG. 3

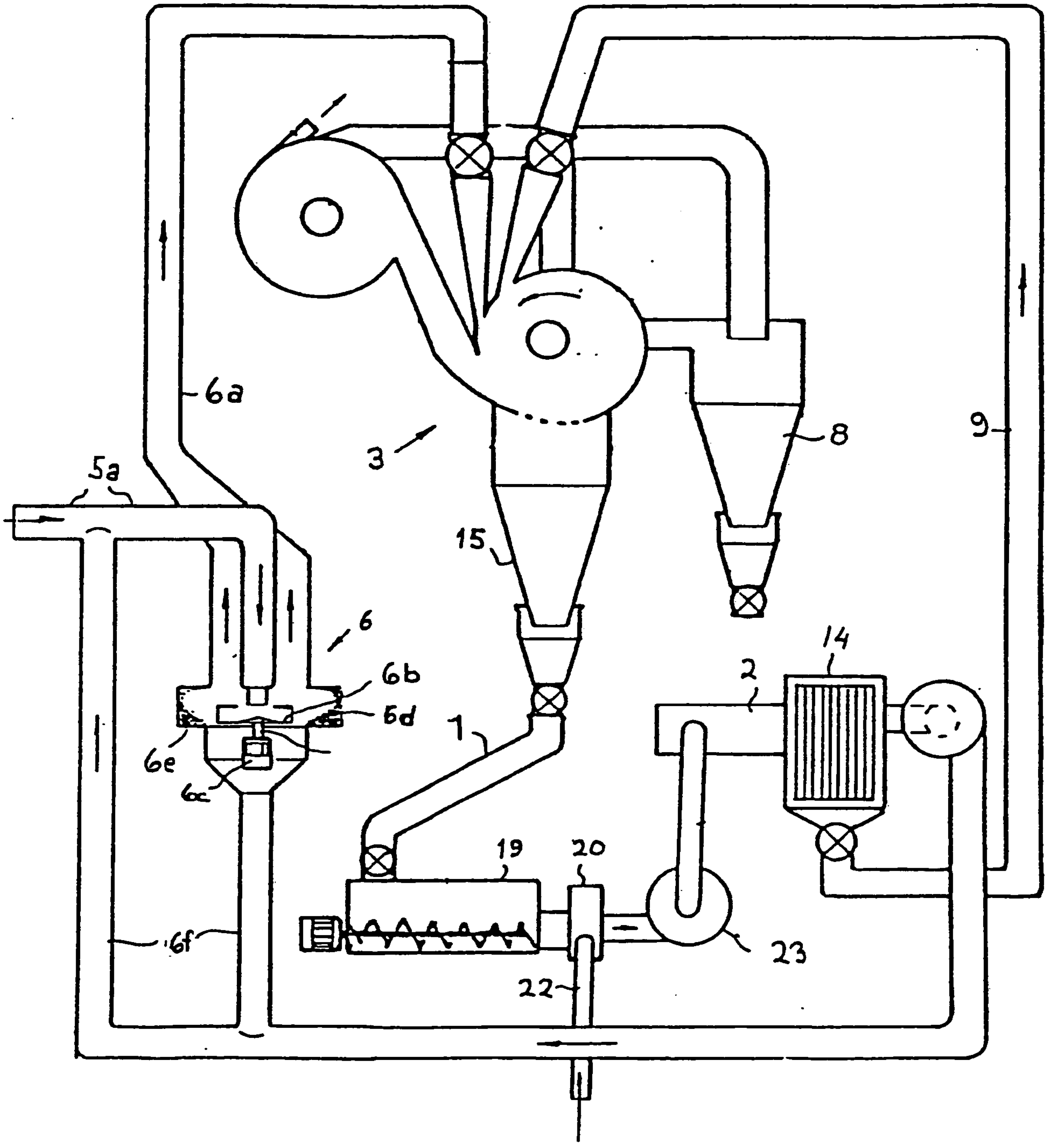


FIG. 4

# INTERNATIONAL SEARCH REPORT

International Application No PCT/FI86/00135

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

B 02 C 19/06

**II. FIELDS SEARCHED**

Minimum Documentation Searched [7]

| Classification System | Classification Symbols |
|---|---|
| IPC 4 | B 02 C 19/06; B 02 C 23/00, /02, /08, /12, /18, /20 /22, /34 |
| Nat Cl | 50c:17/30 .../... |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [9]

| Category [*] | Citation of Document, [11] with indication, where appropriate, of the relevant passages [12] | Relevant to Claim No. [13] |
|---|---|---|
| Y | GB, A, 708 491 (TITAN CO) 18 June 1952 | 1,6 |
| Y | Derwent's abstract No D8374 C/17, SU 682 267 | |
| A | US, A, 2 023 247 (W B SENSEMAN) 3 December 1935 | |
| Y | US, A, 3 289 950 (B H NEUBECKUM) 6 December 1966 | 1,6 |
| Y | US, A, 3 834 631 (T C KING) 10 September 1974 | 1,2,6,8,9 |
| Y | US, A, 3 896 984 (A EDWARDS) 29 July 1975 & FR, 2223281 DE, 2414770 GB, 1422252 AU, 66915/74 CA, 996608 JP, 50026273 .../... | 1,2,6 |

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search | Date of Mailing of this International Search Report |
|---|---|
| 1987-03-05 | 1987-03-10 |
| **International Searching Authority** | **Signature of Authorized Officer** |
| Swedish Patent Office | Catarina Forssén<br>Catarina Forssén |

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Form PCT/ISA/210 (second sheet) (January 1985)

International Application No. PCT/FI86/00135

**FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET**

II

Fields Searched (cont)

US Cl

241: 1, 5, 18, 19, 26, 30, 39, 40, 47, 48, 52

**V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]**

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ........., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ........., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers ........., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

**VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]**

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

International Application No. PCT/FI86/00135

**III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)**

| Category * | Citation of Document, with indication, where appropriate, of the relevant passages | Relevant to Claim No |
|---|---|---|
| Y | US, A, 3 937 405 (N N STEPHANOFF) 10 February 1976 & US, 3903219 DE, 2459624 | 1.6 |
| Y | US, A, 4 131 239 (N N STEPHANOFF) 26 December 1978 | 1,6 |
| Y | US, A, 4 304 360 (R J LUHR) 8 December 1981 | 1,6 |
| Y | US, A, 4 582 264 (N N STEPHNANOFF) 15 April 1986 | 1,6 |